PROTECTIVE POWER AGAINST SALT INJURY OF LARGE ROOT SYSTEMS OF WHEAT SEEDLINGS

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That wheat plants can be made to grow very large root systems as compared with the growth of their tops by certain properties of nutrient solutions, has been shown in a previous paper.[1] The writer has also shown that under certain conditions large root systems of wheat seedlings 4–6 weeks old play an important rôle in the number of tillers[2] the plant may produce. These observations suggested further experimentation where differences in the extent of the root systems of the plants would enter as the variable factor. It seemed plausible to expect that the relative physiological values or growth efficiencies of different nutrient solutions, and the tolerance of plants to salts, were not inconsiderably affected by the extent of the root development of the test plants when placed in the media. The present paper bears upon an investigation on these points.

Three different kinds of nutrient solutions were selected for the tests. These were solutions whose relative values as growth media had previously been obtained. The composition, molecular concentration of the salts, and the relative physiological values of these solutions stated as "good," "medium," or "poor" were as follows:

Solution no. 1.—0.0102 mol. KH_2PO_4; 0.0057 mol. $Ca(NO_3)_2$; 0.0062 mol. $MgSO_4$. Good.

Solution no. 2.—0.014 mol. K_2SO_4; 0.002 mol. $Ca(NO_3)_2$; 0.002 mol. $Mg(H_2PO_4)_2$. Very poor.

Solution no. 3.—0.016 mol. $MgSO_4$; 0.002 mol. $Ca(NO_3)_2$; 0.002 mol. KH_2PO_4. Poor if air temperature and transpiration for growth were high; medium if air temperature and transpiration for growth were relatively low.

[1] GERICKE, W. F., Root development of wheat seedlings. BOT. GAZ. 72:404–406. 1921.

[2] ———, Certain relations between root development and tillering in wheat. (To appear in Amer. Jour. Bot. 9:1922.)

Sets of eight containers (Mason jars) of one-half gallon capacity were used for each of the different solutions and for each of the two different classes of wheat seedlings. These classes of seedlings were distinguished by a difference in the extent of root growth from that of top growth which the plants had when placed in the nutrient solutions. The method employed to obtain seedlings with large root systems was that referred to in the earlier paper. This consisted in allowing the cultures to grow in one quart Mason jars filled with tap water for five weeks before the cultures were placed in the nutrient solutions to be tested. The plants at this time had a root mass 70–80 cm. long, and had about one-half of their total dry matter in the roots. They were transferred from the tap water directly to the three nutrient solutions to be tested. To grow contemporaneously with these, other seedlings (young plants just germinated and therefore having small root systems) were set out in other sets of containers filled with the nutrient solutions to be tested. The seedlings in this latter case were 6–8 cm. high, with roots 8–10 cm. long, about 20 per cent of the dry weight of the plant thus being roots. Subsequent treatment of all cultures was alike, and this included additions of a small amount of $FeSO_4$ to each culture at regular intervals, also regular additions of distilled water to make up the loss of water by transpiration. The test period was six weeks. The experiment was carried on in the greenhouse during parts of July and August, the range of temperature being 20°–32° C. The relative humidity of the greenhouse did not permit excessive transpiration. At the end of the test period, the plants were harvested, dried, and weighed. Table I gives the data obtained.

In taking up the data in detail, it may be noted that the cultures which had large and extensive roots (class *A*), when placed in the "good" nutrient solution no. 1, produced less than one-half as much total dry matter as did the cultures which were started with comparatively small roots (class *B*). The latter class of cultures at the end of the test period had the largest root growth, exceeding by more than 76 per cent that of the next largest. The cultures of class *B* are to be considered as normal plants when set out, the other class not. Even though class *A* had by far the larger roots when the test was started, it is obvious that these large roots did not operate

as a means to secure as great a rate of growth for the plants, especially for the aerial portion, as was obtained by the plants started with relatively small roots having less surface exposed for absorption

TABLE I

EFFECT ON DRY MATTER PRODUCTION OF DIFFERENT ROOT SYSTEMS OF WHEAT SEEDLINGS GROWN IN DIFFERENT NUTRIENT SOLUTIONS (WEIGHT IN GM.)

	CLASS A Cultures having large root systems when placed in solution			CLASS B Cultures having small root systems when placed in solution		
	Tops	Roots	Total	Tops	Roots	Total
			SOLUTION 1			
	1.22	0.42	1.64	3.00	0.73	3.73
	1.13	0.37	1.50	3.29	1.09	4.38
	1.35	0.40	1.75	2.60	0.53	3.13
	1.06	0.38	1.44	3.12	0.95	4.07
	1.38	0.48	1.86	2.95	0.70	3.65
	1.07	0.35	1.42	3.04	0.67	3.71
	1.41	0.55	1.96	3.02	0.62	3.64
	1.15	0.40	1.55	2.97	0.60	3.57
Average.........	1.26	0.42	1.64	3.00	0.74	3.74
			SOLUTION 2			
	1.65	0.43	2.08	0.62	0.12	0.84
	1.42	0.35	1.77	0.60	0.10	0.70
	1.00	0.36	1.36	0.45	0.10	0.55
	1.49	0.37	1.86	0.61	0.12	0.73
	1.38	0.36	1.74	0.75	0.11	0.86
	1.10	0.39	1.49	0.55	0.09	0.64
	1.32	0.37	1.69	0.53	0.10	0.63
	1.10	0.39	1.49			
Average.........	1.30	0.38	1.68	0.59	0.11	0.70
			SOLUTION 3			
	1.00	0.39	1.39	2.94	0.35	3.29
	0.98	0.35	1.33	2.96	0.35	3.31
	1.24	0.42	1.66	3.00	0.46	3.46
	1.61	0.48	2.09	2.40	0.27	2.67
	1.00	0.33	1.33	2.97	0.42	3.39
	1.07	0.30	1.37	*1.62	0.21	1.83
	1.05	0.30	1.35	2.50	0.32	2.82
	1.75	0.37	2.12	2.74	0.39	3.13
Average.........	1.21	0.37	1.58	2.64	0.35	2.99

* Two plants in this culture died.

processes. On the other hand, it is not evident that the large root systems prevented the cultures of class *A* from attaining to the

measure of growth obtained by the cultures of class *B*. That the cultures of class *A* failed to give the measure of growth obtained by the cultures of class *B* must undoubtedly be attributed to some effects of the previous treatment, and of which the large roots in this case apparently may be considered but an incident. In this connection it can be argued that the cultures of class *A* were stunted and did not possess the same potential power or capacity for growth as did those of class *B*, and therefore regardless of any possible beneficial effect, if these large roots meant a greater surface for absorption, this could not compensate to overcome the stunted effects suffered by the plants. Undoubtedly the capacity of a plant to grow is affected by the rate of absorption of nutrients, and vice versa, the rate of absorption of nutrients is affected by the growth of the plants, so that the absorbing capacity of any comparable unit area of root surface must vary with conditions. It appears, therefore, that the data of the cultures grown in solution no. 1, taken by themselves, do not give any indication as to what effects the different root systems had in the results.

The results obtained from solution no. 2 are decidedly different. The seedlings having large roots, when placed in this "very poor" nutrient solution, produced about two and one-half times as much dry matter as did the other class of seedlings grown in this solution. The yield of the cultures of class *A* grown in solution no. 2 were approximately of the same magnitude as those grown in solution no. 1. The yield of the cultures of class *B* having comparatively small roots when placed in solution no. 1 was about five and one-half times larger than that of the corresponding cultures grown in solution no. 2. The explanation for the differences in growth obtained from the two classes of seedlings grown in solution no. 2 seems to be due to differences in the extent of the root systems these cultures had when placed in the media. It is quite obvious that the great difference in total dry weight obtained from the two classes of cultures grown in solution no. 2 is due to the very small growth made by the cultures with small roots, and not to any exceptionally good growth made by the cultures with large roots. The effect of solution no. 2 upon the one class of seedlings (class *B*) was to prevent its making such a measure of root growth as could be necessary to enable the plants to make even a moderate measure of top growth.

The injury to these seedlings was relatively great, therefore, but this was not the case with seedlings having large root growth.

It appears that there are several reasons that can be offered as an explanation for this relatively good growth obtained from the cultures with large roots grown in solution no. 2. The roots of these cultures, presumably because of their age, had much suberized tissue. This could inhibit the entry of excessive amounts of salts. It could also cause the precipitation of some of the salts in the root mass without doing injury to the plants, and, also in a selective way prevent or retard the absorption of toxic ions. On the other hand, this large root system was beneficial to the plant growth in this poor solution, in that it still permitted sufficient absorption of the essential ions. The greater surface exposed to absorption of nutrients, therefore, could compensate for the decrease in the rate of intake of essential nutrients per unit area of root surface.

Results obtained from solution no. 3 show that the plants having comparatively small root systems, when placed in the solution, produced approximately 90 per cent more dry weight than did the other class of cultures grown in this same kind of solution. The dry weight of the cultures of class *B* was also more than four times larger than that of the corresponding cultures of solution no. 2. The growth obtained from class *B* cultures in this solution (no. 3), in which $MgSO_4$ composed eight-tenths of the total salt concentration, must be considered as very good. Had growth conditions prevailed that would have induced a higher rate of transpiration, these cultures would not have attained to the value they held in this test. It is to be noted that these cultures had the lowest percentage of dry matter in the roots of all sets, being 11.7 per cent of the total growth obtained, and constituting a very low value for wheat plants six weeks old. One effect of this solution was to retard root growth in the cultures of class *B* as compared with the growth of top. Under conditions of excessive transpiration this condition would have acted harmfully to the plants. As it was, the cultures of class *B* having the smallest root systems as compared with the tops of the plants appeared to have been the most efficient, if ratio of root growth to top be taken as the criterion.

The dry weight of all the cultures having large root systems (class *A*) when placed in the three different kinds of solutions were

of approximately equal value, having increased approximately five times in weight during the six weeks' period of growth. This test shows that these three solutions, markedly different in composition, must be considered as of equal value as media for the growth of wheat seedlings five weeks old having large root systems, when placed in the solutions and grown for six weeks. These same solutions, however, must also be considered markedly different physiologically, when the test plants are wheat seedlings 6–8 cm. high with small roots 8–10 cm. long.

All the cultures with large roots may be considered as having been injured by the treatment of the first five weeks' growth in tap water, because they fell short in attaining the maximum growth rate obtained by the cultures with small roots (class *B*) in solution no. 1. Whether any treatment that can induce large root growth of a wheat plant, either at the expense of top growth or not, can subsequently be made to operate as a means to secure a greater growth rate for the plant as a whole, because of a greater root surface exposed for absorption, needs further investigation. It is probable that in the present experiment the treatment to obtain large roots was too severe, and that exposure for a less time to the conditions by which large roots were obtained would have given a larger measure of growth when set into these solutions than was obtained.

The extent of the root system appears as an important factor that affects the magnitude of growth obtainable from a given nutrient solution. It is conceivable, therefore, that extent of the root systems of plants plays an important rôle when plants are grown in the field. That some plants are more resistant than others to certain untoward conditions, such as excessive amounts of salts in alkali regions, may not be due to any peculiar genetic factor of the plant, but simply be the response from differences in root development occasioned by certain conditions in the environment in the field. The common observance in the field of a greater tolerance for salts of older plants than young ones apparently can well be accounted for in their root systems. This, however, does not mean that differences in extent of root systems any given kind of plant may have are due only to causes operative in the external environment. Differences in root systems may also be due to genetic factors.

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